California High-Speed Train Project

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High-Speed Train Sound Fact Sheet

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Revision	Date	Description
0	21 June 10	Initial Release – Draft
1	29 June 10	PMT Revisions
2	29 June 10	Authority Comments & Revisions
3	30 June 10	PMT Revisions
4	01 July 10	Authority Comments & Revisions (Barker)
5	02 July 10	PMT Revisions
6	05 July 10	Authority Comments & Revisions (Roelof)
7	06 July 10	Final Version
8	20 July 10	Additional Authority Comments (Barker)
9	09 Aug 10	PMT Revisions Adding Predicted Ldn & Leq Levels
10	16 Aug10	Summary Added
11	18 Aug 10	Added Noise Barrier Reduction Graphic
12	19 Aug 10	Additional Authority Comments (Leavitt)

High-Speed Train Sound Fact Sheet

Introduction

The Federal Railroad Administration (FRA) provides procedures for the assessment of potential noise impacts resulting from proposed high-speed ground transportation (HSGT) projects such as the California High-Speed Train (CAHST) Project. These procedures are presented in the High-Speed Ground Transportation Noise and Vibration Impact Assessment Report prepared October 2005 better known as the FRA Guidance Manual.

The FRA Manual reflects the result of research conducted for the FRA and is presented as part of FRA's efforts to promote the consideration of HSGT as a transportation option in those intercity corridors where it has the potential to be a cost effective and environmentally sound component of the intermodal transportation system.

Experience during previous environmental impact reviews of high-speed rail projects has shown that possible increases in noise are frequently among the potential impacts of most concern to residents in the vicinity of the proposed project. As the interest in HSGT grows and environmental review of HSGT projects is initiated in several locations across the country, it becomes clear to FRA that there is a need to provide a standardized set of procedures for the evaluation of noise impacts. There is also a need to provide guidance to promoters and designers of HSGT projects on ways in which the design of those projects can incorporate measures that address these concerns. And there is a need for providing a means through which public agency reviewers of projects can determine where and to what extent the public benefits of HSGT justify investment in impact mitigation.

Purpose

The purpose of this High-Speed Train Sound Fact Sheet is to provide information to the public and stakeholders of the CAHST Project sections. The fact sheet is prepared in a question and answer format to present the following information:

- What sound is produced by HST?
- Who could be affected by the sound of HST?
- How is the sound of HST described?
- What physical elements of the environment and operational factors affect the sound of the high-speed train?
- What are the estimated sound levels of a HST System?
- How is the audible impact from HST operations determined?
- What can be done to mitigate HST noise?
- What are some of the benefits of HST operations along existing rail corridors?

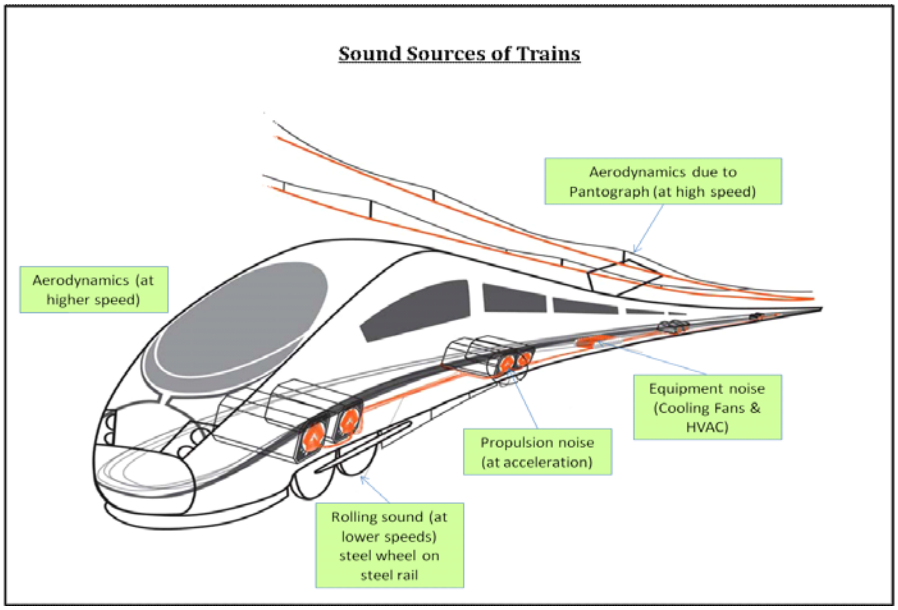
What sound is produced by HST?

High-speed train systems are generally quieter than conventional passenger and freight rail systems for two main reasons:

(1) they are powered by an electric propulsion system and not a diesel engine, which generates higher passby noise; and

(2) HST system requires trackwork that is grade-separated, eliminating at-grade crossings where other railroad trains are required to sound bells at the crossings and warning horns starting at ¼ mile before they reach the crossings.

The total noise generated by a high-speed train passby consists of the electric propulsion system, wheel/rail interactions, and aerodynamic sound produced from airflow moving past the train. At speeds of 160 miles per hour (mph) or less the propulsion system and wheel/rail interactions are the predominant sources of sound. At speeds above 160 mph the aerodynamic sound becomes the predominant source.



Type of Sound	Source
Rolling	Rail surface condition Steel Wheel profile condition Impact Sound Radiation
Aerodynamic	Pantograph Pan Pantograph frame Truck / bogie
Equipment	Ventilation / cooling fans Air-conditioning (roof mounted) Air-conditioning (underfloor)
Propulsion	Air venting Motors, propulsion & gearing Braking

Furthermore the duration of the sound impact is reduced for High-Speed Trains, as the trains operate at faster speeds than conventional trains, thus the passby duration is drastically reduced.

Sound from maintenance facilities, train storage yards, and stations, are substantially the same for any type of rail system and do not have characteristics specific to high-speed train systems.

Who could be affected by the sound of HST?

The FRA defines three categories of land use activities that should be considered in assessing the potential effects of HST operations.

- Category 1 - Tracts of land where quiet is an essential element in their intended purpose. This category includes lands set aside for serenity and quiet, and such land uses as outdoor amphitheaters and concert pavilions, as well as National Historic Landmarks with significant outdoor use.

- Category 2 - Residences and buildings where people normally sleep including homes, hospitals, and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.

- Category 3 - Institutional land uses with primarily daytime and evening use including schools, libraries, and churches, where it is important to avoid interference with such activities as speech, meditation, and concentration on reading material.

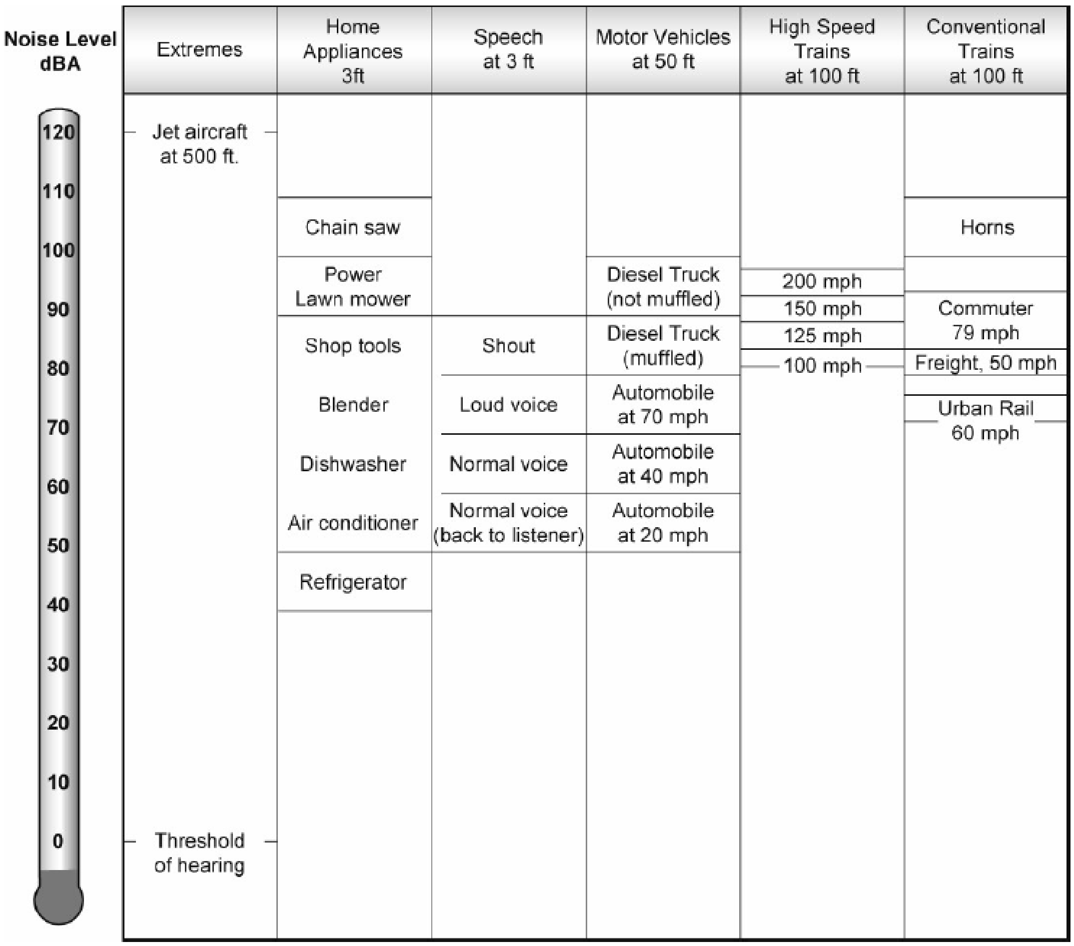
How is the sound of HST described?

The basic unit to describe sound or noise either measured or calculated is the ***decibel or dB***. To better account for human sensitivity to noise, decibels are measured as a weighted measure of sound, abbreviated as dBA, which mimics the human perception of sound, more sensitive at higher frequencies and less sensitive at lower frequencies.

To account for different periods of sound exposure the FRA Guidance Manual describes noise impacts in three ways: 1) the sound of a single train passby, 2) the sound of train operations averaged over the course of an hour, and 3) the sound of train operations averaged over 24 hours using the following noise measurement metrics in dBA:

1) ***Maximum Noise Level (Lmax)***. As a high-speed train approaches, passes by, and then recedes into the distance, the sound level rises, reaches a maximum, and then fades into the background noise. The maximum sound level reached during this passby is called the Maximum Sound Level, abbreviated as "Lmax." For train specifications and noise compliance tests of high-speed trains the Lmax is used. However, Lmax is not used as the descriptor for environmental noise impact assessment for several reasons. Lmax ignores the number and duration of transit events, which are important to people's reaction to noise, and cannot be totaled into a one-hour or a 24-hour cumulative measure of impact. Figure 1 presents typical Lmax levels including high-speed and conventional trains at 100 feet from the listener location.

Figure 1
Typical Lmax

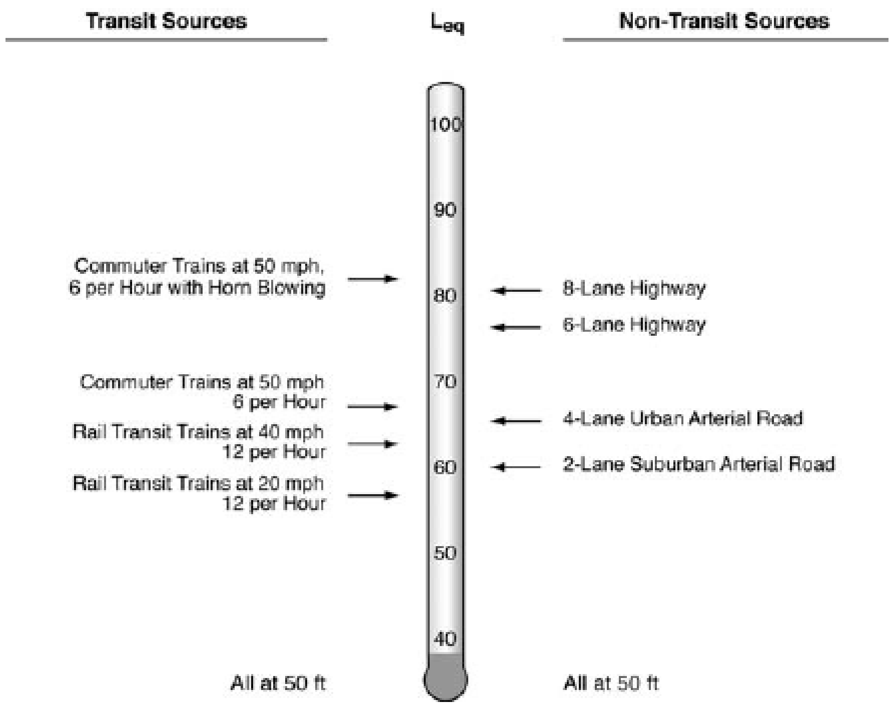


Source: Final Program EIR/EIS for the Proposed California High-Speed Train System, August 2005

2) ***Hourly Equivalent Sound Level (Leq).*** The descriptor for cumulative one-hour exposure is the Hourly Equivalent Sound Level, Leq. It is an hourly measure that accounts for the moment-to-moment fluctuations in sound levels due to all sound sources during that hour. Figure 2 shows some typical hourly Leq's, both for transit and non-transit sources. Typical hourly Leq's range from the 40s to the 80s. One Hourly Leq is used by FRA to evaluate the potential effects of train operations to schools, offices, libraries, and other land use activities that only occur during daytime hours because: (1) Leq's correlate well with speech interference in conversation and on the telephone – as well as interruption of TV, radio and music enjoyment, (2) Leq's increase with the duration of train passbys, which is important to people's reaction, (3) Leq's take into account the number of train passbys over the hour, which is also important to people's reaction, and (4) Leq's are used by the Federal Highway Administration in assessing highway-traffic noise impact. Thus, this noise descriptor can be used for comparing and contrasting highway, transit and multi-modal alternatives. Leq is computed for the loudest hour of train passbys at listener locations such as schools, parks, libraries, and

offices. The one-hour Leq noise levels of high-speed train passbys at different distances and speeds are presented in Figure 4.

Figure 2
Typical Hourly Leqs at 50 feet from the Listener Location

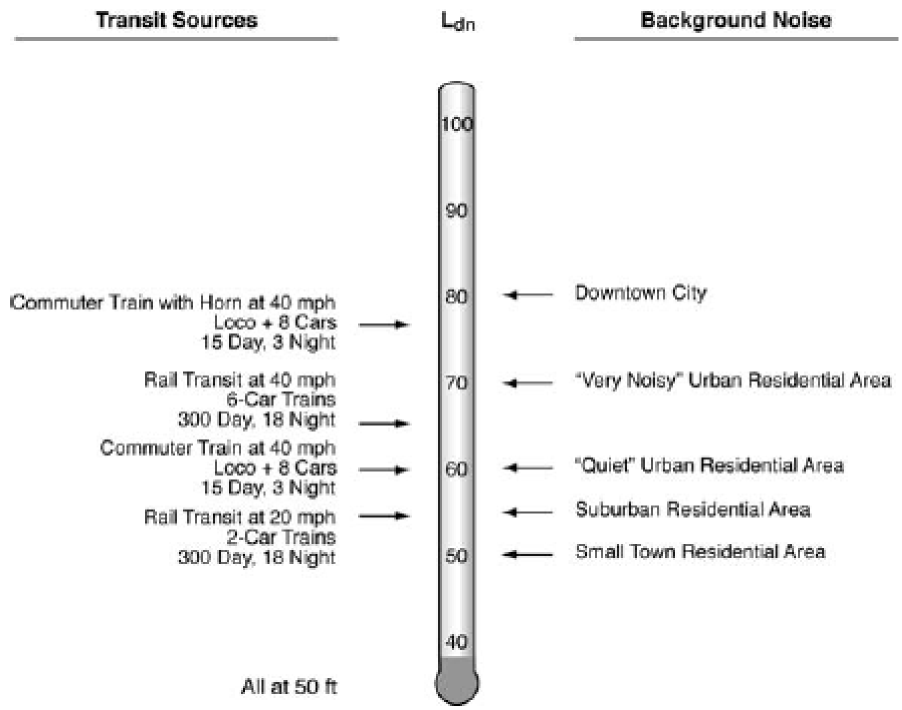


Source: Federal Transit Administration Transit Noise and Vibration Impact Assessment, May 2006

3) ***Day-Night Sound Level (Ldn)*** The descriptor for cumulative 24-hour exposure is the Day-Night Sound Level, "Ldn." It is a 24-hour measure that accounts for the moment-to-moment fluctuations in A-Levels due to all sound sources during 24 hours, combined. Mathematically, the Day-Night Level is computed as an hourly average of the noise over a full 24 hours with events between 10 p.m. and 7 a.m. increased by 10 decibels to account for greater nighttime sensitivity to noise. Figure 3 shows some typical Ldn's, both for transit and non-transit sources. As is apparent from the figure, typical Ldn's range from the 50s to the 70s – where 50 is a quiet 24-hour period and 70 is a loud one. Note that these Ldn's depend upon the number of events during day and night separately – and also upon each event's duration, which is affected by vehicle speed. Ldn is used by FRA to assess potential noise impacts to residential land uses, hotels, motels, and other land uses that have nighttime or sleep activities because: (1) Ldn correlates well with the results of attitudinal surveys of residential noise impact, (2) Ldn's increase with the duration of transit events, which is important to people's reaction, (3) Ldn's take into account the number of transit events over the full twenty-four hours, which is also important to people's reaction, (4) Ldn's take into account the increased sensitivity to noise at night, when most people are asleep, (5) Ldn's allow composite measurements to capture all sources of community noise combined, (6) Ldn's allow

quantitative comparison of transit noise with all other community noises, (7) Ldn is the designated metric of choice of other Federal agencies (Department of Housing and Urban Development (HUD), Federal Aviation Administration (FAA), Environmental Protection Agency (EPA)) and also has wide acceptance internationally. The 24 hour Ldn noise levels of high-speed train passbys at different distances and speeds are presented in Figure 5.

Figure 3
Typical Ldns at 50 feet from Listener Location



Source: Federal Transit Administration Transit Noise and Vibration Impact Assessment, May 2006

What physical elements of the environment and operational factors affect the sound of the high-speed train?

The distance between the train tracks and the listener, the type of ground surface, and the presence of buildings or sound barriers, will all influence the noise level that is heard by a listener at any given location. As defined by the FRA, every doubling of distance from the source to the listener will reduce the noise from HST by approximately 3 dBA to 4.5 dBA depending on the type of ground conditions, either soft grassy ground covering or hard concrete or asphalt surfaces. As an example, at 100 feet the sound from the train will be 3 dBA to 4.5 dBA lower than at 50 feet and at 400 feet 9 to 13.5 dBA lower than at 50 feet. The FRA Detailed Noise Analysis estimates that the presence of buildings between the listener and the train tracks will reduce the passby noise by as much as 10 dBA if the line of sight to the tracks is blocked. Note: A change of 10 decibels is generally considered a doubling or a halving of the perceived loudness of a sound.

The higher train speeds will result in shorter duration of passby. It is expected that a 1300-foot-long high-speed train traveling at 220 mph will take **4 seconds** to pass by a fixed point compared to a 50 car freight train travelling at 30 mph which will take **60 seconds**. When compared to freeway noise high-speed train noise is heard as a very short duration single-event sound as compared to the more constant level of freeway noise which increases in level when heavy trucks, motor cycles or diesel buses passby. Unlike freight rail traffic which often occurs at night, there will not be any high-speed train service during the nighttime hours of midnight to 5 am when people are the most sensitive to noise.

Existing ambient noise levels at a listener location will affect the way high speed train noise is perceived. If a listener is already exposed to noticeable freeway traffic or other noise then the sound of the high-speed train may be less noticeable and they will likely be less affected by high-speed train passbys. Listeners in quieter areas may find high-speed train passby sound noticeable but if they are at greater distances from the train tracks than those in urban settings, then they will experience lower passby sound.

What are the estimated sound levels of a HST System?

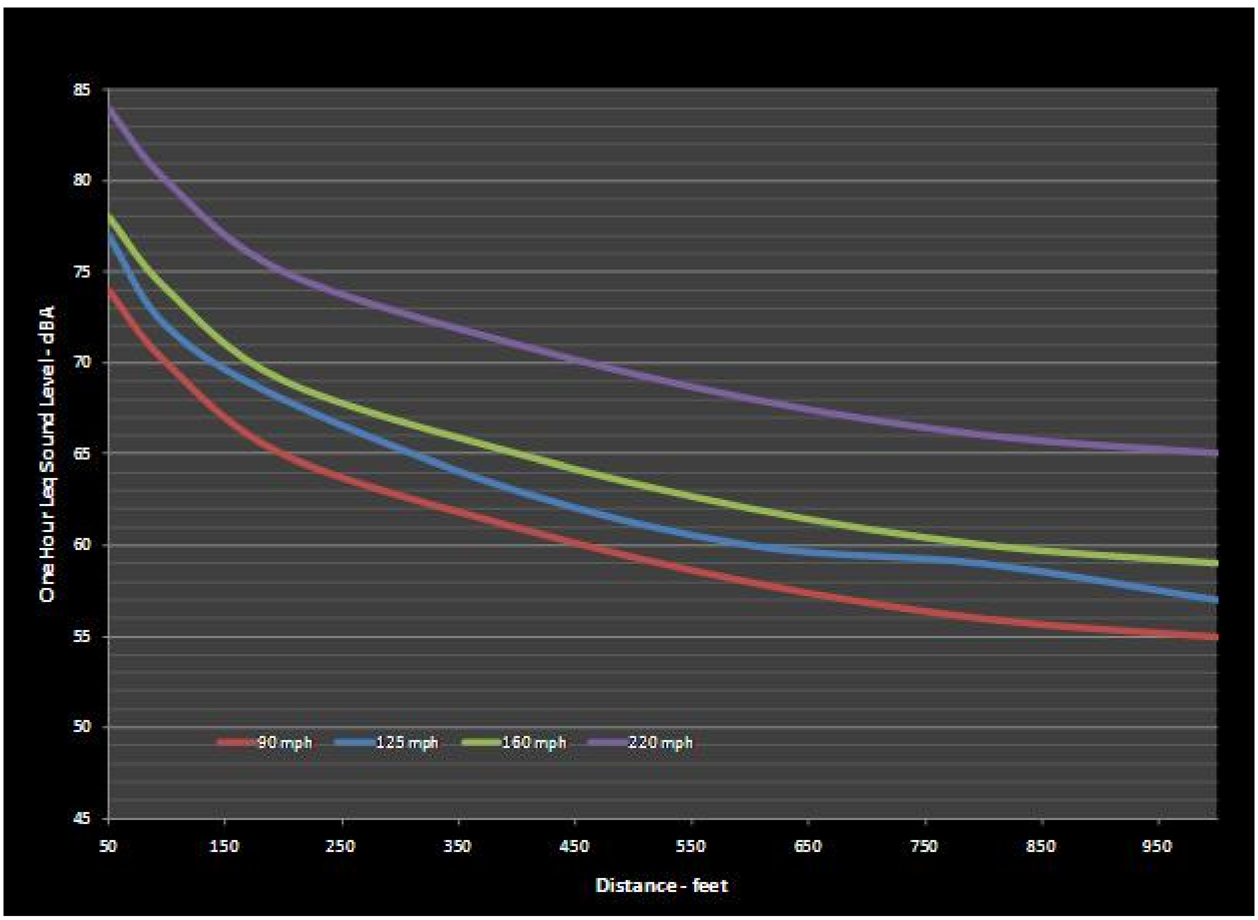
HST passby sound levels will vary depending on train speed and profile, topography, and distance. Figure 4 presents the one-hour Leq noise levels at ground level (where the high-speed train is at grade) that would occur outdoors at distances of 50 to 1000 feet from the centerline of the track for speeds of 90, 125, 160, and 220 miles per hour (mph). These Leq noise levels are based on a maximum of 20 trains per hour. Figure 5 presents the Ldn noise levels at ground levels that would occur outdoors at distances of 50 to 1000 feet from the centerline of the track for speeds of 90, 125, 160, and 220 mph. These Ldn noise levels are based on 258 trains operating during the daytime hours of 7 am to 10 pm and 14 trains during the nighttime hours of 10 pm to 7 am[1]. These noise levels are calculated using the recommended methodology in the FRA Guidance Manual Chapter 5, Detailed Noise Analysis. The FRA methodology derives passby noise levels for high-speed train (HST) operations based on measurements collected in May 1995 by Harris Miller Miller and Hanson for the FRA to develop suitable guidance manual models for high-speed rail noise. Over 100 wayside noise measurements were carried out in three countries on trains operating at speeds up to 150 mph and high-speed trains operating at speeds above 150 mph. These measurements included the TGV and Eurostar high-speed trains in France, and for speeds below 150 mph the Pendolino trains in Italy, and the X2000 trains in Sweden.

Recent noise measurements were conducted by Wilson Ihrig & Associates of the newer train designs currently operating in Asia and Europe. These measurements were conducted at speeds of 120 to 180 mph and, for some of the trainset designs, are in the range of 5 to 6 dBA lower than those predicted by the FRA Guidance Manual at the higher operating speeds of 150 to 180 miles per hour. The FRA data shown in Figure 4 are based on train designs operating in 1995. Newer train designs incorporate enhanced aerodynamic profile to reduce wind noise and also have metal panels on top of the vehicles to smooth the air flow around the catenary system on the top of the train as well as underneath the train around the trucks. The quieter trains also have a distributed power system rather than using a locomotive to haul the passenger coaches, which reduces noise emissions. As California will likely make use of the most modern HS train designs, with distributed power electric motor unit (EMU's) systems these lower sound levels are more indicative of the equipment acoustical characteristics which will be experienced.

[1] Between 10pm to 12am and 5am to 7 am.

Also presented in Figure 5 are the typical Ldn background levels taken from the FTA Transit Noise and Vibration Impact Assessment Report, May 2006 (Figure 3) for different types of settings, downtown, noisy urban residential, and quiet urban residential. These levels represent the average 24 hour Ldn found at listener locations in different environs and can be used to compare with the predicted HST Ldn at different train speeds and distances. For listeners located in a downtown city environs, the HST operations from 90 to 220 mph will be within the existing noise levels from all other sources such as traffic. In a very noisy urban residential area HST operations in the range of 90 to 220 mph will be within the existing noise levels at 250 feet or more from the track centerline. Within quiet urban residential areas the effect of the HST operations will, depending on speed, and could extend to 1000 feet from the track centerline. These comparisons shown in Figure 5 are based on train designs operating in 1995. Newer train designs proposed for the California HST System are expected to be 5 to 6 dBA quieter than the levels presented in Figures 4 and 5. The use of noise (or sound) barriers would further reduce these levels.

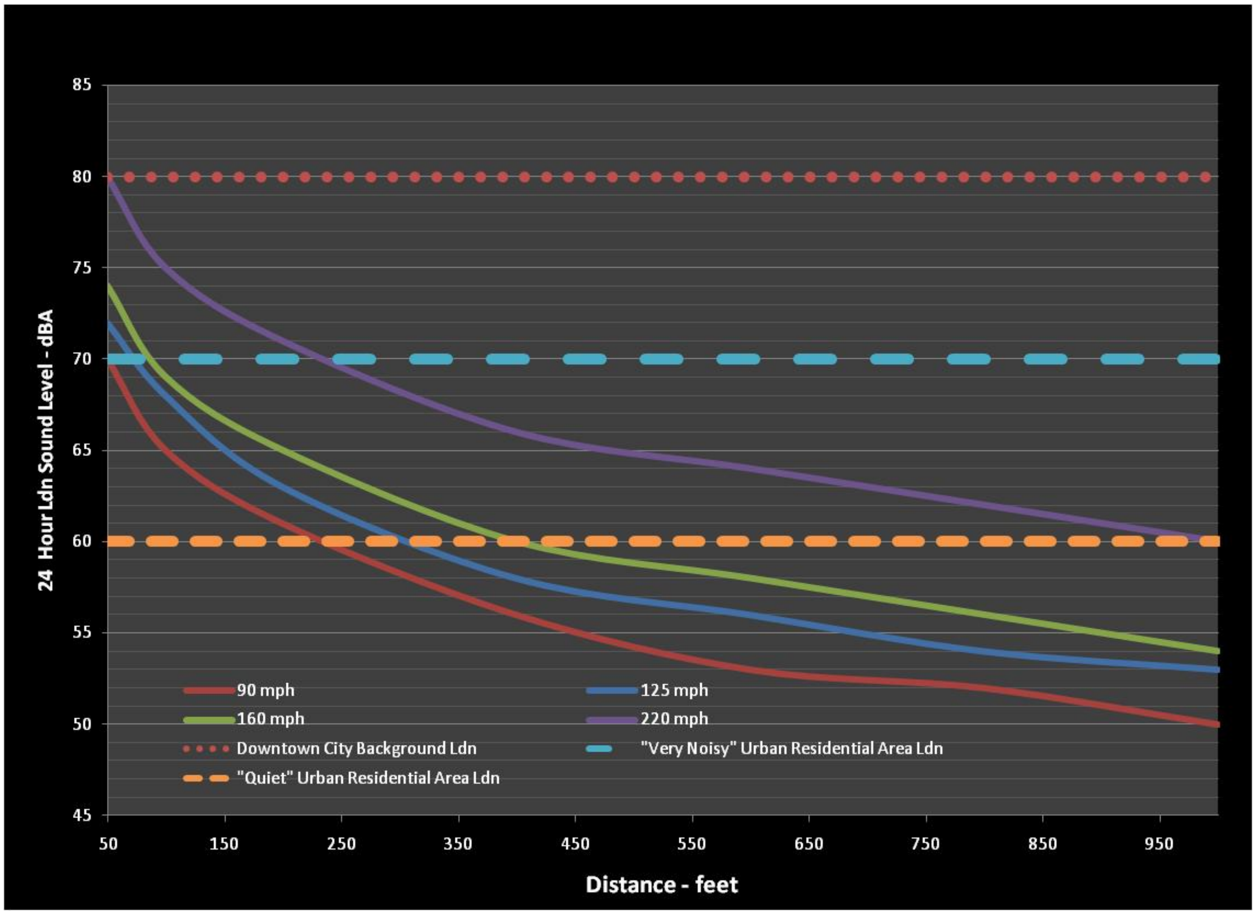
Figure 4
Outdoor HST At-Grade One-Hour Noise Levels (Leq) vs. Distance



Note: HST operations on aerial structures could be 1 to 2 dBA higher than at ground level and if in a trench could be 5 to 7 dBA lower than at ground level. Sound barriers would further improve these sound levels.

Source: FRA High-Speed Ground Transportation Noise and Vibration Impact Assessment, October 2005.

Figure 5
Outdoor HST At-Grade 24 Hour Noise Levels (Ldn) vs. Distance



Note: HST operations on aerial structures could be 1 to 2 dBA higher than at ground level and if in a trench could be 5 to 7 dBA lower than at ground level. Sound barriers could further improve these sound levels.

Source: FRA High-Speed Ground Transportation Noise and Vibration Impact Assessment, October 2005.

How is the audible impact from HST operations determined?

The FRA uses standards and criteria for assessing the audible impacts related to railroad projects developed by the US Environmental Protection Agency (Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, March 1974). The standards outlined in the FRA Guidance Manual are based on community reactions to noise. The standards evaluate changes in existing noise conditions with the added sound from the HST operations. The higher the level of existing noise, the less likely there would be community reaction from additional sound due to the HST operations. Some land use activities are more sensitive to noise than others, such as parks, churches, and residences, as compared to industrial and commercial uses.

Ldn is used to characterize noise exposure for residential areas, and the highest 1-hour Leq (highest cumulative 1-hour noise average) during hours the facility is typically in use is utilized for other noise-sensitive land uses such as schools, libraries, churches, and offices.

An impact at these different noise-sensitive land uses is based on the comparison of the existing noise exposure and the projected future noise exposure from the HST operations. The range of impacts has been determined by FRA using community surveys to help define what levels of sound increase are annoying to the public. The FRA defines three levels of impact:

1. ***No Impact*** is when, on the average, the introduction of HST operations will result in increases in sound that are generally not perceived as annoying to the community.

2. ***Moderate Impacts*** are a change in the cumulative noise level (i.e., HST noise added to existing ambient noise conditions) that is noticeable to most people, but may not be sufficient to cause adverse reactions from the community.

3. ***Severe Impacts*** are considered to occur when a significant percentage of people would be annoyed by the HST noise.

The FRA and the Authority will be reviewing audible impacts to communities and resources along the HST system, determining where such impacts will be significant for these locations, and considering feasible mitigation measures to reduce impacts.

HST sound effects on livestock and wildlife will also be considered. There are no established criteria relating high-speed train noise and animal behavior. A screening procedure will be used by the Authority that has been developed by FRA to identify potential effects of noise from high- speed train operations on domestic and wild animals.

What can be done to mitigate HST noise?

After the inclusion of train design and maintenance techniques to reduce noise generated by the HST system, the most effective noise control treatment for steel-wheeled high-speed rail systems is the installation of sound barriers. These barriers can be sound walls, sound barriers (solid and/or transparent) or earthen berms built between the train tracks and residential or other noise-sensitive areas. The design of the sound walls can vary using concrete, masonry or a combination of opaque and transparent materials. The use of transparent materials for the top of the sound wall would allow riders to view the outside scenery where traditional sound walls may otherwise block the windows of the train. Photographs of HST sound barriers are presented in Figure 6.

The approximate noise barrier lengths, locations, and acoustical design requirements will be developed as part of the engineering design and project noise studies. Train sound barriers should be high enough to effectively block the line of sight between the noise source and the listener. The dominant source of HST sound at speeds of 160 mph or less is the wheel-rail interaction and traction power equipment. To shield this effectively, relatively low barriers located close to the track are usually sufficient and serve as a natural safety barrier for passengers in emergency evacuation situations. In accordance with the FRA Guidance Manual, Detailed Noise Analysis, a barrier with a height of 6 to 12 feet will reduce wheel-rail noise by 5 to 9 dBA. At higher speeds, barrier heights may need to be extended higher than 8 feet to shield the aerodynamic noise from the body of the HST vehicle. The height and

application of the sound barriers would vary depending on whether the tracks are at ground level or below, or elevated on an aerial structure.

Figure 6
Photographs of HST Noise Barriers

Rhine River Viaduct, Germany

Ruyff Valley Viaduct, Germany

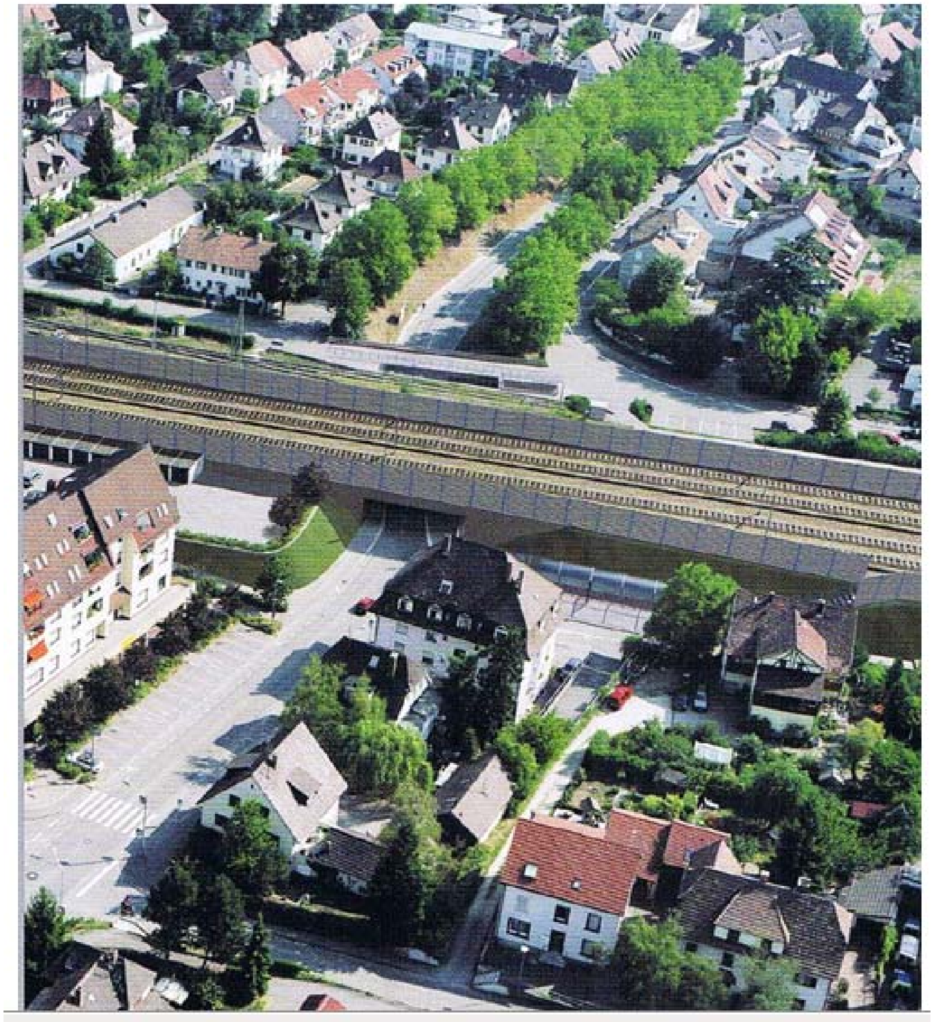
KTX High Speed Train System, Korea

SCNF High Speed Train System, France

Japanese National Railways High Speed Train System

Treno Alto Velocita` High Speed Train System, Italy

Chinese High Speed Train System

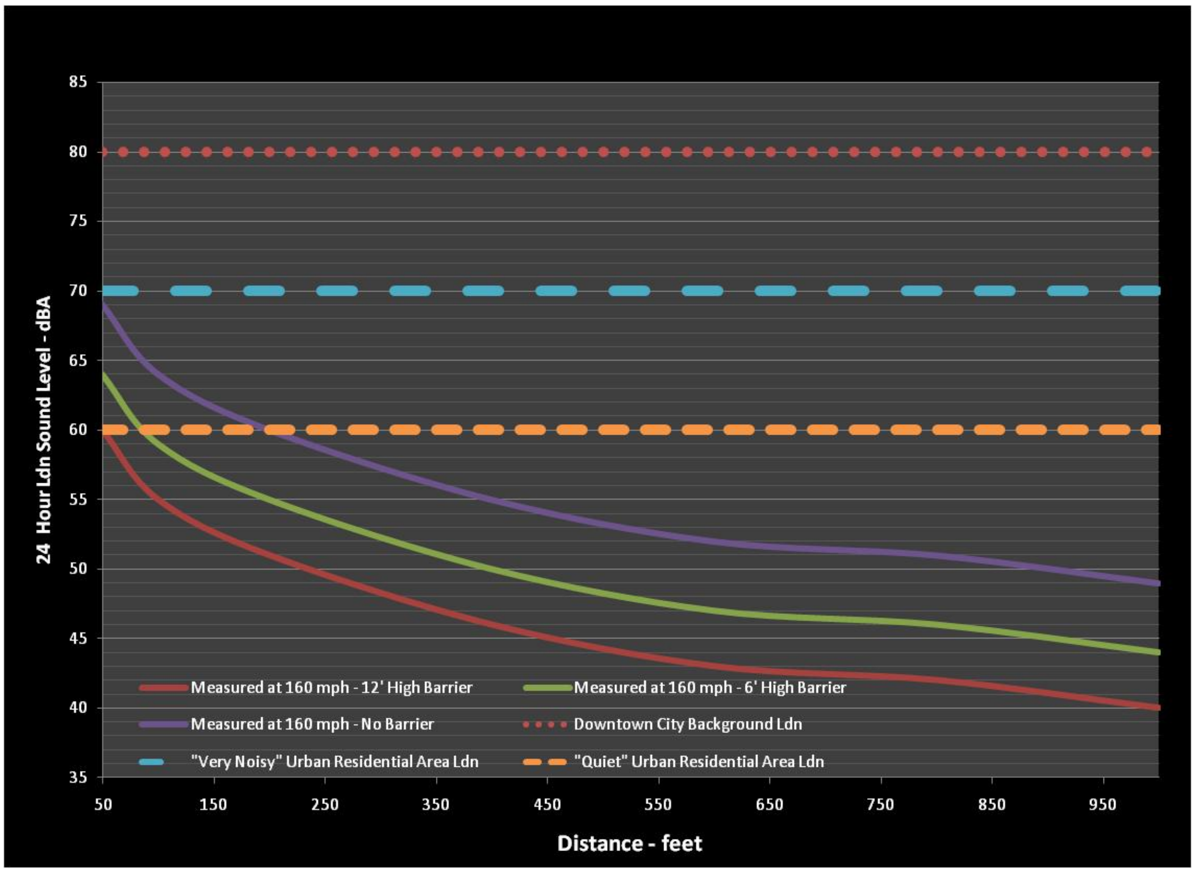


German High Speed Train System

Figure 7 presents the at-grade Ldn of a newer design trainset at 160 mph over distances of 50 to 1000 feet based on the measurements conducted by Wilson Ihrig & Associates in Asia and Europe. Also shown is the expected reduction in Ldn with 6 foot and 12 foot high sound barriers similar to the sound barriers presented in the Figure 6 photographs which are used on other HST systems.

Where sound barriers are proposed, detailed noise barrier designs will be developed during the final engineering phase of the project. Some of the factors to be addressed during the final engineering phase are the structural feasibility and acoustical effectiveness, the aesthetic characteristics of the barriers, as well as their cost effectiveness with respect to their acoustical benefits.

Figure 7
Measured Outdoor HST At-Grade 24 Hour Noise Levels (Ldn) at 160 mph with and without Sound Barriers vs. Distance



What are some of the benefits of HST operations along existing rail corridors?

Where the HST System will grade separate all trains from traffic or in many locations may close the railroad crossing to vehicle traffic next to at-grade HST alignments, the need for warning horns and grade-crossing bells will be eliminated. These grade separations will be designed so that the trains go over or under the road, or the road goes over or under the trains. Local traffic will not have to stop for trains passing which will improve public safety and emergency vehicle access, reduce local traffic congestion, and provide air pollution benefits in addition to the elimination of train horn and grade-crossing bell noise.

SUMMARY

The potential environmental effects of the CA HST system will be evaluated by the methodology and criteria established by the FRA in their Noise & Vibration Guidance Manual. HST operations will be assessed using the following noise descriptors:

- The 24 hour **Ldn** for residential land uses and other land uses where sleep activity occurs such as hotels and hospitals.
- The one hour **Leq** for daytime land uses with no sleep activity such as schools, libraries, and offices.

The HST operations occurring over either the one hour or 24 hour period will be compared to the existing ambient noise levels over the same time period to determine if an impact would occur and if required mitigation measures such as sound barriers would be provided by the Authority.

The Lmax single event noise descriptor will not be used in the environmental assessment of the HST operations but will be used in the vehicle specifications to define the maximum noise limits of the trains.

Since 1995, when the FRA conducted noise measurements of European HST systems, the newer train designs have resulted in lower operating noise levels. Recent noise measurements conducted by Wilson Ihrig & Associates of the newer train designs at speeds of 120 to 180 mph are in the range of 5 to 6 dBA lower than those predicted by the FRA Guidance Manual. Newer train designs incorporate enhanced aerodynamic profile to reduce wind noise. The quieter trains also have a distributed power system rather than using a locomotive to haul the passenger coaches, which reduces noise emissions. As California will likely make use of the most modern HS train designs, with distributed power electric motor unit (EMU's) systems these lower sound levels are more indicative of the equipment acoustical characteristics which will be experienced.